RADAR Titan Flyby during S80/T95

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- Sequence: s80
- Rev: 198
- Observation Id: t95
- Target Body: Titan
- Data Take Number: 253
- PDT Config File: S80_sip_port3_130701_pdt.cfg
- SMT File: s80_130606.smt
- PEF File: z0800a.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T95 Titan flyby. This SAR data collection occurs during the S80 sequence of the Saturn Tour. This is a full radar pass with ride-along SAR, inbound observations over the north polar region, and outbound observations over the south polar region. A sequence design memo provides the science context of the scheduled observations, an overview of the pointing design, and guidlines for preparing the RADAR IEB.

2 CIMS and Division Summary

Each RADAR observation is represented to the project by a set of requests in the Cassini Information Management System (CIMS). The CIMS database contains requests for pointing control, time, and data volume. The CIMS requests show a high-level view of the sequence design. Table 1 shows the CIMS request summary for this observation. Although the CIMS requests show Low-SAR intervals, in reality the radar will be operated in Hi-SAR mode through most of this flyby.

The CIMS requests form the basis of a pointing design built using the project pointing design tool (PDT). The details of the pointing design are shown by the PDT plots on the corresponding tour sequence web page. (See https://cassini.jpl.nasa.gov/radar.) The RADAR pointing sequence is ultimately combined with pointing sequences from other instruments to make a large merged c-kernel. C-kernels are files containing spacecraft attitude data.

A RADAR tool called RADAR Mapping and Sequencing Software (RMSS) reads the merged c-kernel along with other navigation data files, and uses these data to produce a set of instructions for the RADAR observation. The RADAR instructions are called an Instrument Execution Block (IEB). The IEB is produced by running RMSS with a radar config file that controls the process of generating IEB instructions for different segments of time. These segments of time are called divisions with a particular behavior defined by a set of division keywords in the config file. Table 2 shows a summary of the divisions used in this observation. Table 3 shows a summary of some key geometry values for each division.

CIMS ID	Start	End	Duration	Comments
198TI_T95WARMUP001_RIDER	2013-286T19:56:27	2013-286T22:56:27	03:00:0.0	
198TI_T95INRAD001_PRIME	2013-286T22:56:27	2013-287T02:41:27	03:45:0.0	
198TI_T95INSCAT001_PRIME	2013-287T02:41:27	2013-287T03:44:27	01:03:0.0	
198TI_T95IHISAR001_PRIME	2013-287T03:44:27	2013-287T04:25:27	00:41:0.0	
198TI_T95INALT001_PRIME	2013-287T04:26:27	2013-287T04:41:27	00:15:0.0	
198TI_T95RASAR001_PRIME	2013-287T04:41:27	2013-287T05:11:27	00:30:0.0	
198TI_T95RASAR002_RIDER	2013-287T04:50:27	2013-287T05:02:27	00:12:0.0	
198TI_T95OUTALT001_PRIME	2013-287T05:11:27	2013-287T05:26:27	00:15:0.0	
198TI_T95OHISAR001_PRIME	2013-287T05:26:27	2013-287T05:46:27	00:20:0.0	
198TI_T95OUTSCT001_PRIME	2013-287T06:08:27	2013-287T07:11:27	01:03:0.0	
198TI_T95OUTRAD001_PRIME	2013-287T07:11:27	2013-287T10:56:27	03:45:0.0	

Table 1: t95 CIMS Request Sequence

3 Overview

T95 is a full ride-along pass. The observation starts with two inbound radiometer scans looking at the North polar region followed by a scatterometer scan that also includes the North pole. Following this is a high altitude imaging segment with 9 disjointed scan lines that provide fill in imaging over the high northern latitudes. This is followed by regular altimetry and an atmospheric probe measurement. Following this, compressed scatterometry data are collected while turning onto a ride-along SAR swath around closest approach. Ride-along SAR swaths are collected when INMS is the prime instrument and the spacecraft X-axis is maintained in the direction of motion. The radar operates by pointing the -Z axis at Titan to the extent possible, and collecting data while the beams stay on target. This ride-along swath starts in the northern hemisphere, sweeps across the equator near closest approach, and ends in the southern hemisphere. After the ride-along imaging, the radar switches to compressed scatterometry mode to reduce data usage while turning off target followed by another atmospheric probe measurement and eventually turning back on target for an altimeter track. This is followed by another high altitude imaging segment with 5 scan lines quite near the South pole. They cover an area from around -65 deg to -82 deg latitude. Following this is a normal scatterometry raster scan which covers the South pole, and two radiometer raster scans also centered on the South polar area.

4 Mode Specific Operation and Performance

Many details of standard radar sequencing during the 4 main modes (Radiometry, Scatterometry, Altimetry, and SAR) have been discussed in previous sequence memos for prior observations. Refer to these for details. Some selected performance highlights are illustrated in figures and explained in the following subsections.

4.1 Coverage Layout

Figure 1 shows the coverage map for T95. The red jagged lines show the beam centers of the ride-along SAR swath as it sweeps from the northern hemisphere to the southern hemisphere. The violet symbols show the high altitude imaging segments in the polar regions. The green symbols show the altimeter tracks.

4.2 SAR Resolution Performance

For all of the SAR divisions the effective resolution can be calculated from the same equations used in the high-altitude imaging discussion. Figure 2 shows the results from these equations using the parameters from the IEB as generated by RMSS. The calculations are performed for the boresight of beam 3 which is the center of the swath.

Projected range increases with decreasing incidence angle, so the range resolution varies across the swath with better resolution at the outer edge. The SAR pointing profile decreases the incidence angle as time progresses and altitude increases, so there is progressive deterioration of range resolution away from closest approach. The projected

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-9:20:0.0	03:30:0.0	12.5	Warmup
b	standard_radiometer_inbound	-5:50:0.0	00:05:0.0	0.3	radiometer quick-steps
c	standard_radiometer_inbound	-5:45:0.0	03:20:0.0	11.9	radiometer raster
d	standard_scatterometer_inbound	-2:25:0.0	01:09:0.0	124.2	Inbound scatterometry raster
e	scatterometer_imaging	-1:16:0.0	00:31:0.0	111.6	Inbound scatterometer imaging
f	scatterometer_imaging	-0:45:0.0	00:05:0.0	21.0	Inbound scatterometer imaging
g	scatterometer_imaging	-0:40:0.0	00:10:0.0	51.0	Inbound scatterometer imaging
h	standard_scatterometer_inbound	-0:30:0.0	00:01:48.0	3.2	Inbound scatterometry during turn to alt
i	standard_altimeter_inbound	-0:28:12.0	00:08:12.0	15.7	Inbound altimetry
j	standard_scatterometer_inbound	-0:20:0.0	00:00:4.0	0.6	Atmospheric Probe with Chirp
k	standard_scatterometer_inbound	-0:19:56.0	00:00:2.0	0.3	Atmospheric Probe with Tone
l	scatterometer_compressed	-0:19:54.0	00:01:42.0	0.3	Compressed Scatt/Rad scan
m	scatterometer_compressed	-0:18:12.0	00:11:12.0	2.0	Compressed Scatt/Rad scan
n	standard_sar_hi	-0:07:0.0	00:02:0.0	16.8	Inbound Ridealong SAR
o	standard_sar_hi	-0:05:0.0	00:10:0.0	138.0	Left look Ridealong Main SAR Swath
p	standard_sar_hi	00:05:0.0	00:02:0.0	16.8	Outbound Ridealong SAR
q	scatterometer_compressed	00:07:0.0	00:14:56.0	2.7	Compressed Scatt/Rad scan
r	standard_scatterometer_outbound	00:21:56.0	00:00:4.0	0.6	Atmospheric Probe with Tone
s	standard_scatterometer_outbound	00:22:0.0	00:00:2.0	0.3	Atmospheric Probe with Chirp
t	standard_altimeter_outbound	00:22:2.0	00:05:58.0	11.5	Outbound altimetry
u	scatterometer_imaging	00:28:0.0	00:01:30.0	5.8	Outbound scatterometer imaging
v	scatterometer_imaging	00:29:30.0	00:11:30.0	44.9	Outbound scatterometer imaging
w	scatterometer_imaging	00:41:0.0	00:10:0.0	39.0	Outbound scatterometer imaging
x	scatterometer_imaging	00:51:0.0	00:23:0.0	82.8	Outbound scatterometer imaging
y	standard_scatterometer_outbound	01:14:0.0	01:01:0.0	109.8	Outbound scatterometry raster
z	standard_radiometer_outbound	02:15:0.0	03:45:0.0	13.4	Outbound radiometry
Total				836.9	

Table 2: Division summary. Data volumes (Mbits) are estimated from maximum data rate and division duration.

Div	Alt (km)	Slant range (km)	B3 Size (target dia)	B3 Dop. Spread (Hz)
a	180388	off target	0.23	off target
b	112367	off target	0.14	off target
c	110741	off target	0.14	off target
d	45520	47528	0.06	207
e	22975	23138	0.03	362
f	12904	13805	0.02	586
g	11295	12115	0.02	653
h	8116	8946	0.01	844
i	7552	7552	0.01	890
j	5046	5046	0.01	1181
k	5026	5026	0.01	1184
l	5016	5016	0.01	1185
m	4517	5587	0.01	1268
n	1685	2496	0.01	2108
o	1347	1643	0.00	2289
p	1347	1643	0.00	2289
q	1685	2447	0.01	2108
r	5625	5625	0.01	1098
s	5645	5645	0.01	1095
t	5655	5655	0.01	1094
u	7490	7490	0.01	896
v	7959	8455	0.01	856
w	11616	11878	0.02	638
x	14843	14986	0.02	523
y	22323	22696	0.03	371
z	42252	43468	0.06	219

Table 3: Division geometry summary. Values are computed at the start of each division. B3 Doppler spread is for two-way 3-dB pattern. B3 size is the one-way 3-dB beamwidth

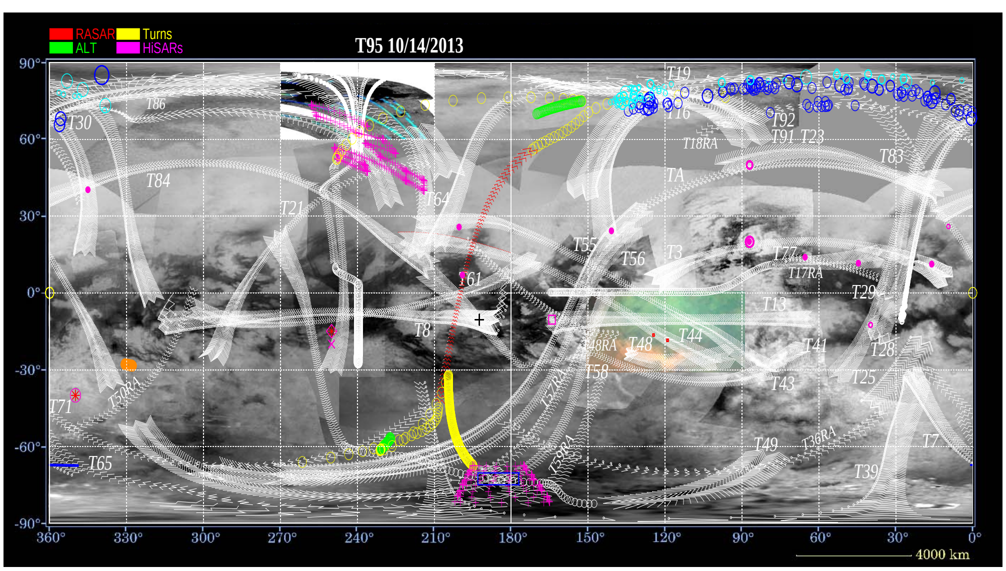

Figure 1: Coverage areas overlaid on Titan map showing prior optical and radar imaging. Ride-along SAR in red, high altitude imaging in violet, altimeter tracks in green, and turn transitions in yellow.

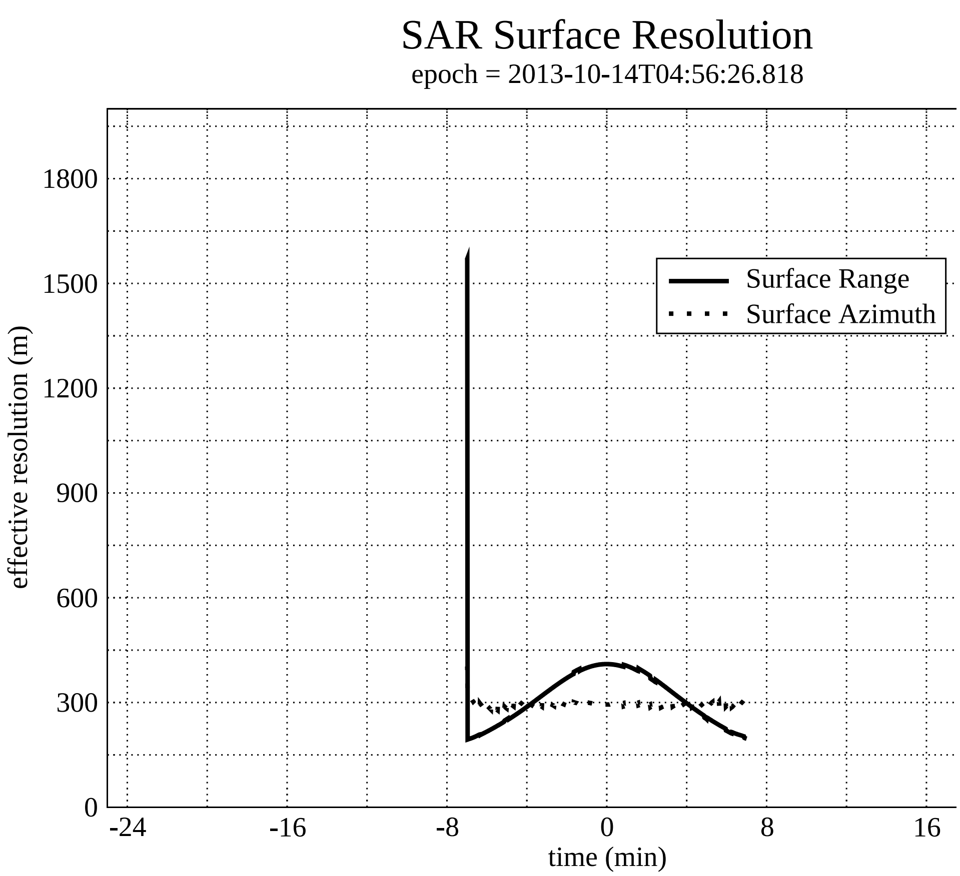

Figure 2: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

range resolution rapidly deteriorates as the incidence angle decreases toward zero at the very beginning and end of the swath and during the close approach altimetry segment.

Azimuth resolution is a function of the synthetic aperture size which is determined by the length of the receive window in each burst (assuming the receive window is always filled with echos). Azimuth resolution deteriorates less quickly because the number of pulses and the length of the receive window are increased as altitude increases which mitigates the increasing doppler bandwidth of the beam patterns. The receive window length increases to fill the round trip time until the science data buffer is filled. At this point it is no longer possible to extend the receive window, and azimuth resolution starts to deteriorate more rapidly.

5 Revision History

1. Sept 15, 2014: Final release

6 Acronym List

ALT	Altimeter - one of the radar operating modes
BAQ	Block Adaptive Quantizer
CIMS	Cassini Information Management System - a database of observations
Ckernel	NAIF kernel file containing attitude data
DLAP	Desired Look Angle Profile - spacecraft pointing profile designed for optimal SAR performance
ESS	Energy Storage System - capacitor bank used by RADAR to store transmit energy
IEB	Instrument Execution Block - instructions for the instrument
ISS	Imaging Science Subsystem
IVD	Inertial Vector Description - attitude vector data
IVP	Inertial Vector Propagator - spacecraft software, part of attitude control system
INMS	Inertial Neutral Mass Spectrometer - one of the instruments
NAIF	Navigation and Ancillary Information Facility
ORS	Optical Remote Sensing instruments
PDT	Pointing Design Tool
PRI	Pulse Repetition Interval
PRF	Pulse Repetition Frequency
RMSS	Radar Mapping Sequencing Software - produces radar IEB's
SAR	Synthetic Aperture Radar - radar imaging mode
SNR	Signal to Noise Ratio
SOP	Science Operations Plan - detailed sequence design
SOPUD	Science Operations Plan Update - phase of sequencing when SOP is updated prior to actual sequencing
SSG	SubSequence Generation - spacecraft/instrument commands are produced
SPICE	Spacecraft, Instrument, C-kernel handling software - supplied by NAIF to use NAIF kernel files.
TRO	Transmit Receive Offset - round trip delay time in units of PRI